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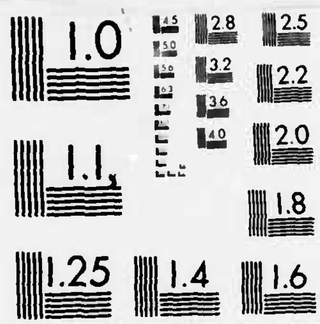

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NUCLEAR TERRORISM EFFECTS STUDY

Terry Donich

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December, 1983

Lawrence Livermore National Laboratory

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In this report we discuss the technical problems associated with predicting the consequences of a nuclear terrorism event, a summary of LLNL capabilities, and some suggested approaches to the problem.

The normal method applied to evaluate the nuclear effects is to scale free-field calculated nuclear effects to the small-yield urban environment. This approach can be very misleading because the size of the structures that surround the detonation may radically change the important characteristics

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20. ABSTRACT (cont.)

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Of the approaches presented as solutions to this problem, the systems approach is recommended. The possibility of prioritizing the effort using a risk analysis approach is also discussed.

SUMMARY

In this report we discuss the technical problems associated with predicting the consequences of a nuclear terrorism event, a summary of LLNL capabilities, and some suggested approaches to the problem.

The normal method applied to evaluate the nuclear effects is to scale free-field calculated nuclear effects to the small-yield urban environment. This approach can be very misleading because the size of the structures that surround the detonation may radically change the important characteristics of the explosion which in turn may change the nuclear effects on the surrounding population and area.

Of the approaches presented as solutions to this problem, the systems approach is recommended. The possibility of prioritizing the effort using a risk analysis approach is also discussed.

INTRODUCTION AND BACKGROUND

In this report we will discuss the technical problems associated with predicting the consequences of a nuclear terrorism event, LLNL capabilities, and some suggested approaches to the problem.

Earlier studies[1] have looked at the overall problem of nuclear terrorism. For purposes of this report, we will assume that the adversary can obtain the necessary people, special nuclear materials, precision machining capability and high explosives materials to accomplish the task of constructing a nuclear device. The nuclear device is assumed to be a small-yield (less than a few tens of kilotons) fission device. Larger yields are also possible.

A nuclear device could be placed in a myriad of urban locations in order to accomplish the goals of the terrorist organization. The simplest location from a technical analysis point of view may be an open street in a simple transporting mechanism such as a trailer or van. Most other locations will add complexity to the problem. For purposes of discussion, we will use the open street location.

First, the threat assessment, search, and location phases normally associated with a terrorist threat must have been completed. Then, the problems of identification and diagnosis and either "render safe" or "mitigation and evacuation" are to be accomplished. For purposes of this report, it is assumed that mitigation and evacuation are the elements of interest. In addition to being heavily interrelated, mitigation and evacuation are also related to the device identification phase.

The first questions that have to be answered to determine the size of the area to be evacuated are those concerning the type and expected yield of the device and expected level of mitigation achievable. However, for planning an evacuation, it would be prudent to assume mitigation is a negligible item for

safety of the population and is only a reasonable approach for reducing property damage. In addition, this assumption is valid because there is a non-zero probability that the device may be set off automatically or manually during the application of mitigation techniques. Although techniques are being investigated that do not require massive amounts of material and long times for application, they will not be ready for use in the immediate future. It should also be noted that mitigation techniques will most likely be useful only in very few device locations.

For evacuation planning, the device type and expected yield will be very important. Although information about the device type is expected to be relatively easy to obtain, the expected yield will be very difficult to assess. Assuming the device can neither be rendered safe nor disassembled and that a large amount of time is not available for detailed diagnosis, the device must be assumed to have a yield range from just the high explosive yield to the maximum credible yield of nuclear material contained in the device. Even estimating the maximum credible yield requires that a tremendous number of assumptions be made about the nuclear material in the device. If the actual yield is just the high explosive portion of the total potential yield (i.e., a nuclear dud), then the dispersal of nuclear material in an oxide state will probably be the dominant problem. Prompt effects, such as blast, thermal, and ionizing radiation, will be very small or absent. As the yield increases from this low level to one where part of the yield is of nuclear origin, the dispersal of radionuclides will be an increasing problem, at least in the size of the surface area contaminated. However, the effects of blast, thermal, and ionizing radiation will quickly become very important also. The effects of the end points of this process (high explosives only and maximum nuclear material yield) have been studied in certain environments for the military as the safety/accident problem and the normal weapons effects, respectively. The nominal weapons effects are discussed in Glasstone and Dolan.[2] Many other documents (e.g., from DNA[3]) discuss weapons effects in free-field environments. However, even these factors have not been adequately addressed in the surface burst urban environment where massive concrete/steel structures may dominate the problem. The relative size is shown in Fig. 1.

For the strategic case, the military has been interested mostly in optimum height of burst for maximum overpressure on a target. The size of the fireball and damage area is very large compared to the building size as shown in Fig. 2. The tactical nuclear case (especially with the neutron bomb) has caused a shift from this maximum overpressure approach. However, the use of neutron bombs would most likely be in a more open environment rather than in an urban environment, and a modified free-field analysis is used for this case also.

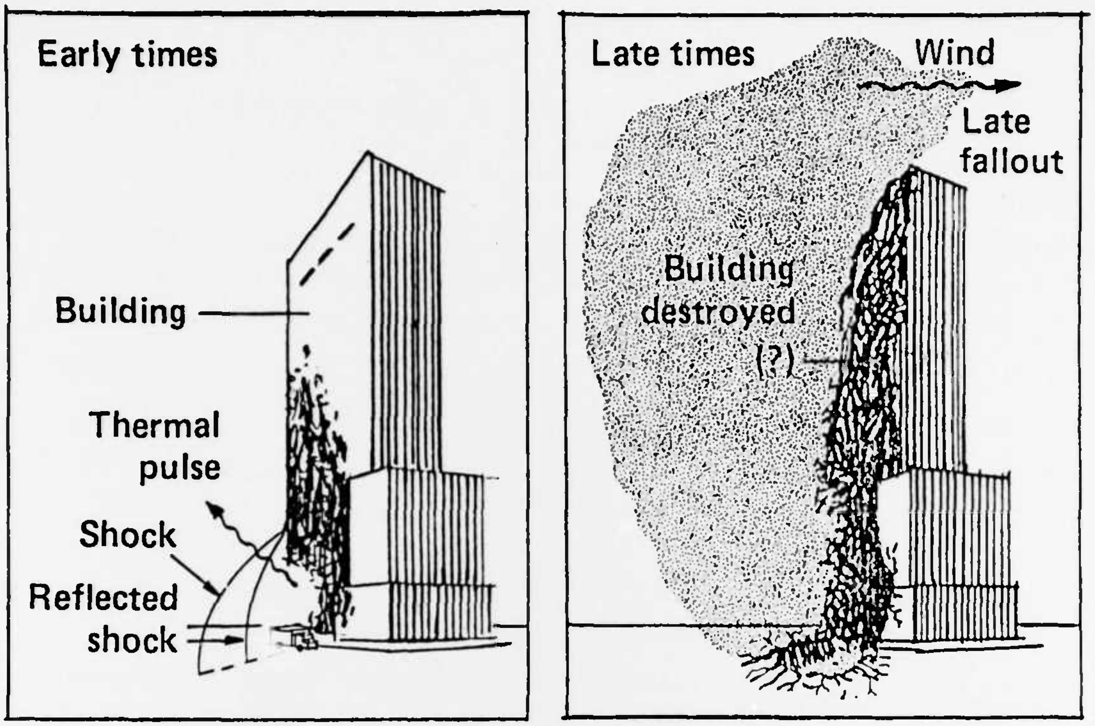

Fig. 1. Schematic of Low-Yield Urban Case

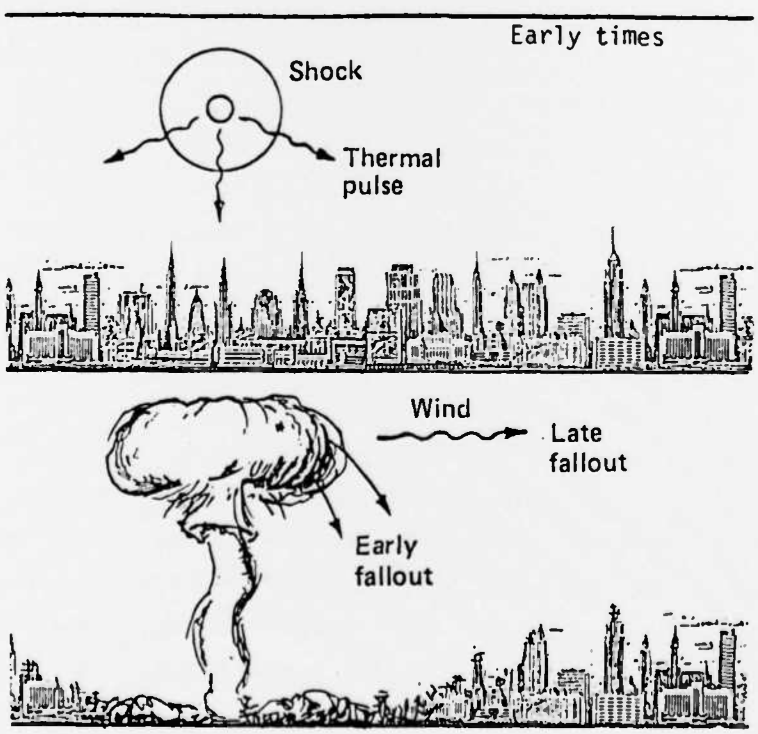

Fig. 2. Schematic of Normal Strategic Case

TECHNICAL PROBLEMS ASSOCIATED WITH THE URBAN ENVIRONMENT

In an urban environment, such as Manhattan, with the device on the surface of a street, several mechanisms will come into play that do not exist in the free-field environment. First, the thermal and ionizing radiation output of the device will heat the close surroundings of the device, and some of these surroundings (e.g., buildings on two sides) will emit this energy back into the fireball in an asymmetrical fashion. The shockwave will also build up on the sides of the non-rigid, and possibly collapsing, buildings and be reflected non-symmetrically back into the fireball. The competition of these effects along with the restricted ability of the fireball to "breathe" (i.e., the inrush of cool air is heated causing the fireball to rise) may bring about a strong ballistic component to the rise as opposed to a buoyant rise normally assumed for a small yield fission device. This would have a major effect on the radioactive fallout and dispersal.

The shockwave in the direction of the street (as opposed to the direction of the building) would be channeled and directed down the street. The surrounding buildings and structures would cause drag on this shock front, and depending on the building surfaces, large scale roughness factors may rapidly remove energy from the wave by turbulence build-up. Breakage of glass walls with blast filling of buildings would also remove energy. At street intersections, a pressure relief will occur down side streets and an associated eddy fluid flow and turbulence pattern will build up to remove energy from the shock front. Another problem to be considered might be the collision of shock fronts channeled in different routes in the grid of streets. When this phenomenon occurs, the result will be a loss of shockwave energy that will heat the fluid. Although the problems mentioned above have been studied individually for various fluids, the ability to comprehensively study these effects for a nuclear explosion in an urban environment does not currently exist. If one removes all of the problems above with simplifying assumptions, models are available to coarsely treat the problem. The uncertainty in the results from these models is so large when coupled with the uncertainty in the device yield that it makes the result nearly useless to the emergency planner.

The thermal problem is somewhat easier to analyze. The major considerations are the objects and people in the streets, since this wavelength of radiation energy does not penetrate opaque objects but rather heats them. The temperature of the fireball constrained by the structures of the urban environment when viewed at a distance from the burst probably will not change significantly from the normal 6000K to 7000K and only the cross-sectional area of the radiating surface will have to be considered. The majority of the thermal energy (approximately one-third of the total energy from the device in a free-field environment) will be emitted in a few tenths of a second. At street level, the thermal pulse will come from a volume of luminous gas that will approximate a cylinder filling the area between the buildings and be of a height approximating the radius of the normal free field fireball hemisphere. At times after the thermal pulse, the fireball should exhibit some jetting and movement down the street. This is the result of the pressure created by partial early-time containment on two sides by the buildings, but the buildings will not play a major role in the very early time fireball that gives rise to the thermal pulse. This assumes the yield is 10 kT or less, so the thermal pulse is short.

The fallout problem associated with the urban environment may be the most difficult and overriding in terms of evacuation planning. The problem is to understand the dominant factors in order to determine what fraction of the nuclear debris cloud will rise above the surrounding buildings. As mentioned earlier, the partial blast containment, the radiation and thermal heating of structures, the full involvement of building material in the condensation chemistry, and the "breathing" ability of the cloud will all have an effect on cloud rise. Although recent new fallout models have brought this effect to a level of predictability associated with other nuclear effects in a free-field environment, the effort has never been seriously attempted for an urban environment[4].

A second major problem is to estimate a meteorological surface roughness to be used for an urban environment over large areas that will receive fallout. The surface roughness is used to estimate the turbulence and eddy

fluid flow conditions and consequently the air mixing near the ground surface. It should be noted that although fallout a long way downwind does arrive in time lengths of hours, the moderately close fallout (less than one kilometer) can start arriving within a few minutes. Thus, the portion of the population close-in that takes cover during the explosion should not try to outrun the fallout. The rescue effort will have to be well planned and executed to save them. Protection factors of building shielding from fallout may be good enough to protect them for the time needed to plan the area re-entry. In particular, the center areas of midlevel floors in a high-rise building should be reasonably safe.

LLNL CAPABILITIES

During this task, a review of LLNL capabilities was conducted. This review consisted of discussions with a number of groups and divisions involved with nuclear effects. As a result of this review, the discussion below highlights some of the capabilities of the computational tools. The discussion is divided into radiation transport, coupled hydrodynamics radiation transport, fallout generation and transport, living system interaction with ionizing radiation and radionuclide uptake. The area of EMP is excluded from this discussion.

The radiation transport code used for most close-in applications is called TART-NP which is basically a two-dimensional (surface represented by quadratic equations) Monte Carlo transport code for neutrons and gammas[5]. It was developed at LLNL several years ago and continues to be improved and supported by the Laboratory. There are versions of this code for the CDC 7600 and CRAY-1 computers at LLNL. This code was used as a part of a recent recalculation of the effects at Hiroshima and Nagasaki[6,7]. Those calculations have enabled LLNL scientists to understand the leukemia mortality data differences at the two cities.

A second code used for radiation transport is the DOT code imported from Oak Ridge National Laboratory several years ago and highly modified at LLNL[8]. In its present form, it is a discrete ordinate solution of the transport equation set in a static geometry. Its use has primarily been to investigate radiation transport over long distances where Monte Carlo techniques are prohibitively expensive. This code runs on a CDC 7600.

A coupled hydrodynamic radiation transport code can be used to compute the transport of neutrons and photons from gammas to infrared and include the interactions with plasma thermal ions and material surfaces. Such codes designed for problems in cylindrical symmetry use a Lagrangian approach to computation. Such codes have been used to investigate questions in fireball mechanisms, ground coupling and thermal output. Such codes operate on a CDC 7600 or a CRAY-1 computer.

Several classified hydrodynamic codes developed at LLNL are being used to study underwater effects, particularly shock interaction with structures. These codes all run on a CDC 7600 or CRAY-1.

The Atmospheric Science Division has several computational tools to model long-range climate changes due to stratospheric alterations and surface pollutants as well as codes to model radionuclide fallout from nuclear accidents and detonations. The ARAC[9,10] center in this division is linked to the large main frame CDC 7600 and CRAY-1. One of the fallout codes KDFOC2[11,12] is a fast running system code. This code has also been compared to the Nevada Test Site data for 10 land surface and shallow buried bursts. The agreement is significantly better than methods used in the 1960s and 1970s. Coupled together with other data bases available at LLNL, it provides an assessment tool with great flexibility and capability.

LLNL also is working in the technical area of rainout of radionuclides. This phenomenon produces locally very high doses in isolated areas because of the effect of the rain drops in scavenging radionuclides from fallout clouds. These areas that would normally receive a small amount of fallout could receive a very heavy amount of radionuclides with rainout. The codes to predict this effect are currently not named, but they are available.

The Biomedical Division has several computer models for doses to biological systems through air, water, and food pathways[13]. Most of these models have been recently tested against data taken from the Pacific test series during 1950 and 1960 and the Nevada Test Site data[14,15].

The "JANUS" tactical nuclear game simulation at LLNL is currently used to train military command personnel and also is used for war game simulation studies[16]. It has the ability to operate as a "red team" vs "blue team" in real time operations. Although it is very complete in modeling terrain effects for personnel, weapons systems, intelligence operations and nuclear weapons effects, it cannot handle the urban environment being discussed. It is conceivable that it could be modified to handle this type of environment at a future time in order to work out various evacuation procedures for FEMA.

LLNL also has capabilities in the area of operations research. These capabilities are currently being used to model both strategic and tactical warfare in order to make system trade-offs and to optimize the system performance. These same type of studies could be used by the emergency planners to optimize the response to a given nuclear terrorist activity.

LLNL participates in the NEST effort from threat assessment phase to location and render safe phase discussed in the Introduction. This effort, coupled with the various NEST working groups' participation, will provide a broad background capability in nuclear terrorism.

All of the models mentioned along with current effort at LLNL provides a high technology base from which to build a nuclear terrorist response program at LLNL. The application of these tools to that program are discussed in the next section.

CONCLUSIONS AND RECOMMENDATIONS

The analytical tools presently available to treat the problems discussed in this report are extremely limited. Problems of this type require complicated three-dimensional treatment and are very difficult to analyze. It should be noted that the street location discussed previously is one of the easiest to analyze from a technical point of view. Other locations such as in a building, an underground shallow facility, or a ship may be much more difficult to analyze. The case where a device is located on the top of the tallest building in the area may be the single case where current state-of-the-art capability could provide a credible assessment.

Three avenues of approach are possible to investigate this problem: 1) a first-principle investigation; 2) a continuation of the free-field scaling approach; and 3) a systems level approach. These will be discussed below.

The first-principle approach is technically a very challenging problem. Each of the effects would be treated from first principles in differential equation form on a moderately fine mesh or grid computer model. The major problem with this approach is that the cost can be in the millions-of-dollars range, and results cannot be expected for several years. This approach should be treated as a research program in which many details would be investigated but only the dominant ones kept in the problem. Besides the cost and time factors, the ability to validate the results through experimental testing is almost impossible for this approach. For these reasons, this approach is not recommended even though it could potentially reduce the uncertainties by the largest margin.

The second approach, that of continuing to use scaled results from free-field data, does not look inviting either. The major problem is that the assumptions used in this approach make most of the important competing effects disappear, and the uncertainty in the results increases tremendously.

Examples of this include the effects mentioned in the cloud rise model for fallout. Although this approach may be better than doing nothing, it may also mislead the planner into making very serious mistakes.

Of the approaches suggested, the system approach seems to have the most merit. This method uses expert opinion on dominant mechanisms, analytic fits to solutions, and simplifying "back of the envelope" computer models to estimate the importance of the mechanisms. Sensitivity studies using these models are run to determine the importance of the mechanisms. The computer models for the mechanisms found to be most important are then improved. The sensitivity studies are repeated to see if the results change. In this process, when the results do not change significantly, you have gained some confidence that the uncertainty can be bounded.

As a part of the system approach, a shock fluid dynamics code that can account for drag factors and multichannels would have to be found or developed to assess the blast problem. This code would have to account for the constraints and reactions of the close-in massive structures. The thermal and ionizing radiation transport could most likely be assessed by current models such as TART-NP or a coupled hydrodynamic radiation transport code with some modifications for the urban environment. Such a code could be considered first principle approaches also. However, as envisioned here a more simplistic approach to modeling buildings and surroundings would be used. The fallout could be evaluated using the KDFOC2 code. A new cloud rise model would have to be developed to estimate the nuclear debris cloud heights, and the various radionuclide stratification altitudes.

The systems approach also has another attribute; that is, the concept of a risk analysis that can be used in order to sort or prioritize the relative importance of each effect for different scenarios. Risk takes into account the expected frequency of occurrence of malevolent acts and the potential effects or consequences on society. It is represented by the expression

Risk = (Frequency of occurrence) x (magnitude of consequence.)

The system work can be used to give a measure of the magnitude of consequences. The frequency of occurrence is estimated from actual data, where available, and expert opinion otherwise. The risk measure of the various nuclear scenarios effects can be evaluated and prioritized. This methodology is an aid in selecting the most important (highest risk) effects to be better understood from a mitigation or close-in evacuation planning point of view. It is expected that the system approach would cost a few hundred thousand dollars per year for two to three years in order to develop the tools and analyze several possible locations in an urban complex. A risk assessment to prioritize this work is estimated to require about one man-year of effort.

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